# Improved Agricultural Technology Adoption in Zambia: Are Women Farmers Being Left Behind?

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**Working Paper 106**
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The Indaba Agricultural Policy Research Institute is a non-profit company limited by guarantee and collaboratively works with public and private stakeholders. IAPRI exists to carry out agricultural policy research and outreach, serving the agricultural sector in Zambia so as to contribute to sustainable pro-poor agricultural development.

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Any views expressed or remaining errors are solely the responsibility of the authors.

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## EXECUTIVE SUMMARY

The use of modern seed varieties and other improved technologies is essential for farmers to significantly increase their crop harvest and improve their livelihoods. All over Sub-Saharan Africa, agriculture productivity growth has remained very low over many decades irrespective of gender of the farmer. However, studies have shown that women farmers fare worse than the male counterparts in terms of adoption of improved technology and productivity. This gender gap in technology adoption curtails agricultural development because women in developing countries such as Zambia play a significant role in agriculture and food production.

Although there are many studies on technology adoption and productivity difference by gender, the links between gender and productivity is likely to vary across cultures and over time, hence the need to carry out this study in the Zambian context. Some studies have found that productivity differences between men and women could be explained by the difference in the rate of adoption of improved technology, the intensity with which the inputs are used as well as resource differences.

Using nationally representative household panel survey data supplemented by results from focus group discussions, this paper explores the factors contributing to gender differences in technology adoption and the effectiveness with which inputs are used to produce an output (technical efficiency) by men and women famers. The study provides answers the following questions:

1. Are there any gender differences in access and use of productivity resources among smallholder farmers in Zambia?
2. What are the factors that contribute to the gender differences in technology adoption?
3. What is the extent to which gender differences in access to inputs such as land, labor, credit, and extension services contribute to lower rates of adoption of improved technologies among women farmers?
4. Does the presence of a male-head in a household affect the adoption behavior of women smallholder farmers?
5. Are there any gender differences in crop production efficiency?

As opposed to the traditional way of using gender of the household head to determine the gender differences in technology adoption and productivity, our analysis is able to discern at household level the plot decision makers. Furthermore, we take into consideration women in male- and female-headed households to evaluate their adoption behavior.

### The Following Key Findings Emerge from Our Study:

1. Men generally were more likely to access credit, extension services, own and cultivate more land, and had high productive assets value compared to women. However, women in male-headed households were more likely to access agricultural extension services, credit, labor, and land compared to women in female-headed households.
2. Adoption of improved technologies (fertilizer, hybrid seed, herbicides, and animal traction) was more prominent on plots owned (controlled) by men than women. Female farmers were less likely to adopt hybrid seed, fertilizer, and use of animal traction compared to their male counterparts.
3. Female farmers in male-headed households who had access to credit were more likely to adopt hybrid seed compared to female farmers in female-headed households who also had access to agricultural credit.

4. Access to extension services by female farmers both in the male- and female-headed households had a positive effect on adoption of fertilizer and hybrid seed however, the variable is not significant on adoption of hybrid seed for female farmers in female-headed households.
5. The maize technical efficiency among male farmers is 7% higher than for female farmers. However, the difference in maize technical efficiency is mostly explained by disparities in resource endowment rather than the gender of farmer.

Results in this paper strongly calls for finding practical ways of closing the gap in access to productive resources between male and female farmers. This will help increase technology adoption and productivity on female-controlled plots. In addition, promoting market participation by women farmers increases the adoption of improved seed and use of fertilizers among this group of farmers. Furthermore, access to affordable rural finance and more robust extension services will help improve the rate of adoption among smallholder farmers.

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## ACRONYMS

| | |
|---|---|
| CRE | Correlated Random Effect |
| CSO | Central Statistics Office |
| FAO | Food and Agriculture Organization |
| FGDs | Focus Group Discussions |
| FHH | female-headed households |
| FISP | Farmer Input Support Program |
| FRA | Food Reserve Agency |
| HCI | Household Commercialization Index |
| HH | household head |
| IAPRI | Indaba Agricultural Policy Institute |
| IFAD | International Fund for Agricultural Development |
| LR | likelihood ratio |
| MAL | Ministry of Agriculture and Livestock |
| MHH | male-headed households |
| MLE | maximum likelihood estimation |
| MT | metric tons |
| RALS | Rural Agricultural Livelihoods Surveys |
| SFA | Stochastic Frontier Approach |
| SSA | Sub-Saharan Africa |
| TE | Technical Efficiency |
| USAID | United States Agency for International Development |
| ZNFU | Zambia National Farmers Union |

# 1. INTRODUCTION

Women in developing countries play a very significant role in agricultural production particularly in their labor contribution. They are responsible for nearly half of the world's food production and produce between 60-80% of the food in the developing countries (FAO 2005). In Zambia for instance, 78% of the women are engaged in agriculture compared to 69% of men (Sitko et al. 2011). However, despite their significant contribution in agriculture, women have less access to agricultural resources such as land, labor, and credit than men (FAO 2010; Meinzen-Dick et al. 1997; Gregorio et al. 2008). And according to the International Fund for Agricultural Development (IFAD), though female farmers are primary contributors to the world's food production, they are frequently underestimated and overlooked in development strategies (IFAD 2010). Agriculture production in rural areas is often undermined by gender-related constraints and unequal access to productive resources. In order to achieve substantial growth and poverty reduction through agriculture, there is need to effectively address the constraints that women face both in production and market participation. Women's productivity in agriculture is therefore highly dependent on their opportunity to having access to productive resources such as land, credit, extension, and other agricultural technologies (Ragasa 2012).

Studies that have looked at adoption of new (improved) technologies have recognized that access, ownership, and control over productive resources are critical elements in determining a farmer's capacity to adopt such technologies. Though both men and women smallholder farmers face a number of constraints in accessing productive resources, the constraints are more acute among female farmers who also face cultural barriers in accessing certain resources such as land. For example, a study on gender and access to agricultural resources by smallholder farmers in Ghana shows that there is a significant relationship between the gender of the farmer and access to labor (Anaglo, Boateng, and Boateng 2014). They found that men had more access to labor compared to their female counterparts; similar results have been reported by Dillon and Quiñones (2010) that labor constraints were more acute for female-headed households than male-headed households in Nigeria. This is because to a large extent, women farmers mostly depend on their own labor and unpaid labor that is within their households. The problem of poor financing among women farmers does not allow them to hire labor extensively compared to men. Therefore, availability of unpaid family labor is critical to women farmers who cannot afford to hire labor.

Furthermore, a number of studies have shown that women farmers face cultural restrictions in accessing land than men and they generally control land that is of poor quality with insecure tenure (FAO 2010). The study by Mukuka (2013) in Chongwe district of Zambia shows that women had less access to land compared to their male counterparts. The author indicated that even when women do own or have access to land they often had limited access to agricultural support services such as credit with which they can purchase inputs. In Sub-Saharan Africa, the most common way that women gain access to land is through marriage where land is allocated to them to their husbands. Though they may gain access to land through their husbands, they do not gain ownership of it (Doss 2008).

Similarly, farmers interviewed in the focus group discussions in Zambia indicated that traditionally, land was mostly accessed through the head of the household who in most cases was male. While women can only acquire land from traditional leaders if they were divorced, widowed, or single and there is no older male child within that household. In some parts of Zambia, it is considered a taboo for married women to request for land from traditional leaders.

The study by Ragasa et al. (2013) shows that female heads and plot owners in Ethiopia were less likely to get extension service than the male heads and plot owners. The authors indicated that besides the gender of the farmer, access to extension services was affected by the level of education, landholding size, and proportion of males within the households. Thus, the *gender gap* in access to agricultural resources and services is likely to affect the rate at which women adopt new technologies and it can hinder women's productivity, thereby, reducing their contributions to the agricultural sector.

A review of gender studies and agricultural productivity in Sub-Saharan Africa (SSA) show that male-headed households are more likely to adopt new technologies compared to female-headed households (see Quisumbing 1996; Thapa 2009; Peterman, Behrman, and Quisumbing 2010; Ragasa et al. 2013). However, when resource differences between male- and female-headed households are controlled for, results from most of such studies suggest that females are equally likely to adopt new technologies as their male counterparts. This suggests that if the resource gap is closed, then we can see women become more productive. In addition, other studies have found that the results were influenced by location and culture. Hence, more country specific gender disaggregated studies are required to deepen our understanding about the reasons behind the lower rate of adoption and productivity among women farmers.

Understanding the factors that affect the adoption of improved technologies by women and men farmers is key in identifying the policy interventions that are gender sensitive and needed to improve the productivity of all smallholder farmers. For example, if men and women face the same constraints but their rate of adoption of new technologies is different, then it will be imperative to design technologies that best fit the needs of each group. On the other hand, if the difference in the rate of adoption is because men and women face different constraints, then it will be important to address this unequal access to such complementary inputs in order to promote broad based agricultural growth among all smallholder farmers (Doss and Morris 2000).

Furthermore, studies that have analyzed the productivity differences by gender show that women are less productive than men are. However, these studies fail to take into account the resource disparities that exist between men and women. For example, a study by Udry et al. (1995) found that in Burkina Faso, plots controlled by women had significantly lower yields than plots controlled by men for the same crop. The differences in yield did not imply that women are less efficient cultivators than men are, rather these differences are due to higher labor and fertilizer use on plots controlled by men. Similarly, a review of gender differences in agricultural productivity by Quisumbing (1996) found that there was no significant differences in technical efficiency between men and women farmers. She found that yield differences were caused by differences in the intensity with which inputs such as labor, manure, and fertilizer were used on plots controlled by men and women. Therefore, productivity differences between men and women can be explained by the difference in the rate of adoption of improved technology and the intensity with which the inputs are used. Although there are many studies on technology adoption and productivity difference by gender, the links between gender and productivity is likely to vary across cultures and over time, hence the need to carry out this study in the Zambian context.

Using the Zambia maize subsector as a case study, this paper aims to answer five key research questions as follows:

1. Are there any gender differences in access and use of productivity resources among smallholder farmers in Zambia?

2. What are the factors that contribute to the gender differences in technology adoption?
3. To what extent does gender differences in access to inputs such as land, labor, credit, and extension services contribute to lower rates of adoption of improved technologies among women farmers?
4. Does the presence of a male head in a household affect the adoption behavior of women smallholder farmers?
5. Are there any gender differences in maize production efficiency?

The study contributes to the body of knowledge in several ways. First, we build on lessons learned on methodological limitations outlined by Peterman, Behrman, and Quisumbing (2010) and Quisumbing (1996). Second, unlike many studies, our study deals with the problem of endogeneity of input use decisions. Third, our study goes beyond just making a comparison between male-headed households versus female-headed households. Instead, we explore other gender groups such as gender of plot decision maker, females in male-headed households and females in female-headed households. These additional distinctions will help us examine the influence of intra-household dynamics. Lastly, the study utilizes a very comprehensive two-wave national rural livelihood survey that makes it possible to report results for the whole country.

The remainder of this paper is organized into five sections: Section 2 presents methods including a brief description of the conceptual framework used in the study. A brief description of the data used is presented in section 3, while Section 4 highlights the descriptive findings and econometrics results. Section 5 presents the conclusion and recommendations.

## 2. CONCEPTUAL FRAMEWORK AND METHODS

This section begins by outlining the conceptual framework on which our estimation models are based after which we discuss the methods.

### 2.1. Conceptual Framework

Modeling the farm households' behavior is key in understanding the technology adoption patterns of smallholder farmers in Zambia. Economic theory assumes that households choose the best collection of commodities (practices) consistent with the limited resources available to them. Therefore, when the farmer/decision-maker is faced with multiple technical options (agricultural practices), observed outcomes can be modeled within the framework of discrete choice analysis. While the decision-maker may be presented with a number of alternatives to choose from, the feasibility and attractiveness of each alternative within the choice set often depends on a number of constraints, including physical and financial resources, information availability, and level of education as well as technical complexity and performance of the technology (Ben-Akiva, Moshe, and Bierlaire 1999).

According to Doss (2001), given the alternative inputs to choose from, the choice of which inputs to use and in what quantities will be dependent on the objective function of the individual farmer (i.e., the farmer may be maximizing profits or maximizing household food security). Therefore, if the purpose for growing the crops is for sale, the primary concern is profitability, while for home consumption the farmer will be more concerned about storage, and processing as well as taste. These factors and many others may affect the decisions made by men and women smallholder farmers to adopt or not adopt a particular technology.

We view technology adoption by men and women smallholder farmers from the collective models or cooperative bargaining models of the household's viewpoint where individuals are assumed to have different preferences but resources are pooled within the household. The model suggests that factors that affect an individual's utility or wellbeing outside the household will affect his or her bargaining power within the households. These factors include individual's income, access to land, and other resources. For example studies have shown that women's access to land, credit, and other resources outside the household affects their access to resources within the household as well as their decision making power Quisumbing and Maluccio (2000); Doss (2006). In addition, according to Doss (2001), technologies that affect which person earns and controls income may affect the outcomes of household decisions including agricultural production decisions. Similarly, with regard to technology adoption, the household models suggest that if men and women have different preferences regarding agricultural production or consumption, the bargaining power of individuals will affect the outcomes of decisions. In light of that, studies that have looked at technology adoption by men and women have observed that access to productive resources (land, credit, information, etc.) affects the rate of adoption by the two groups of farmers. In some cultures, married women cannot own land independently— they have to access land through a *conjugal contract* with their husbands.

### 2.2. Estimation Strategy

Most of studies that have looked at adoption of improved technologies by smallholder farmers have used cross-sectional data that makes it difficult to control for unobserved heterogeneity across households. Unobserved heterogeneity may exist in form of farmers' ability and management skills, soil quality, and many other factors that may affect the farmers' decision to adopt or not adopt a particular technology. Thus, the decision to adopt a particular technology was modeled using a panel binary choice model.

The latent model of adopting either hybrid seed, fertilizer, herbicides, or animal traction is specified as:

$$Y_{it}^{*} = X_{it}\beta + \varepsilon_{it}\,, \quad i = 1, 2, ., N; t = 1, ., T \tag{1}$$

$$\varepsilon_{it} = \alpha_i + U_{it} \tag{2}$$

Where $Y_{it}^{*}$ is a latent dependent variable, $Y_{it}$ is the observed binary outcome variable indicating the adoption of either of the technologies stated above defined as:

$$\mathrm{Y_{it}} = \begin{cases} 1, \text{if } i \text{ adopts} \\ 0 \ \text{ otherwise} \end{cases} \tag{3}$$

We estimate separate regressions for four outcome variables of interest using panel data methods and the general model is given as:

$$Y_{it} = \beta_0 + X_{it}\beta + \alpha_i + U_{it} \tag{4}$$

$X_{it}$ , represents a vector of time-varying and time-invariant exogenous variables such as socio-economic characteristics of the household and individual characteristics of the household head. Also included are community variables and agro-ecological Zones. $\beta$ represents a vector of parameters to be estimates; $\varepsilon_{it}$ is composite error term which can be decomposed into $\alpha_i$, a term capturing unobserved individual or household heterogeneity and $U_{it}$ a random error term. The subscript *i* and *t* refer to individual households and time periods respectively. To estimate more precise $\beta s$ parameters our study follows Mundlak (1978) and Chamberlain (1984) Correlated Random Effects (CRE) approach. We use CRE probit model to control for time-invariant unobserved heterogeneity ($\alpha_i$); this is implemented by including mean values of time-varying explanatory variables in equation (4). This approach allows for correlation between the unobserved effects and the observed explanatory variables.

The explanatory and dependent variables used in our econometric model are defined in Appendix 1. We use four different dependent variables to explain the adoption of improved seed varieties, fertilizer, and herbicide use as well as the use of animal traction. A number of individual and household characteristics have been included in the model as covariates. The analysis for the econometric model is conducted on households that had maize fields. We use gender of the plot (field) owner to identify the plot manager who makes the decisions about land management and other production decisions. The conventional approach in most adoption studies is to use the gender of the household head but we further use two dummy variables to represent female plot owners in male- and female-headed households. Other variables included in the model are some plot characteristic such as use of manure (compost), whether the plot is susceptible to soil erosion and the type of tillage method used in that particular field. We also include dummy variables for the agro-ecological zones to control for the differences in the agro-climatic conditions that could affect the profitability of these technologies.

Secondly, to examine the factors associated with productivity differences by gender (male- versus female-controlled plots), we estimate a maize yield response model using the Stochastic Frontier Approach (SFA)[1]. Using SFA enables us to determine the Technical Efficiency (TE), thus the effectiveness with which inputs are utilized to produce the output (in our case maize) and how far the different farmers are operating at the full capacity with their available resources. Equations 5 and 6 motivate the SFA approach. For the $i^{th}$farmer/household,

$$Y_{it} = f(X_{it}, Z_{it}) + \varepsilon_{it} \tag{5}$$

Where $Y_{it}$ is the output per hectare by farmer i, in a given year $f(X_{it}, Z_{it})$ is the maximum output attainable from $X_{it}$, a vector of physical inputs, and $Z_{it}$ is a vector of other control variables that are hypothesized to affect production and $\varepsilon_{it}$ is the disturbance term. However, in this model, our interest is on the disturbance term $\varepsilon_{it}$ (Green, 1993). In particular, $\varepsilon_{it}$ is a two-component disturbance term of the form:

$$\varepsilon_{it} = v_{it} + \mu_{it} \tag{6}$$

$v_{it}$ captures the variation in output resulting from factors that are beyond the control of the farmer such as weather, price shocks whilst the other component $\mu_{it}$ measures the extent to which observed output deviates from potential output and captures farm specific technical inefficiency in production. The technical inefficiency term ($U_{it}$) is assumed as a function of a vector of explanatory variables ($Z_{it}$) and unknown parameters ($\delta$) to be estimated. In a linear equation, the technical inefficiency effects can be specified as follows:

$$U_{it} = \delta Z_{it} + W_{it} \tag{7}$$

For a comprehensive review of stochastic frontier literature (see Forsund, Lovell, and Schmidt 1980; Greene 2008).Two functional forms are commonly used in the estimation of stochastic frontier models; Cobb-Douglas and Translog functional forms. Both functional forms are linear in parameters and thus can be estimated in a linear regression framework. However, the Translog presents a more flexible functional form as opposed to the Cobb-Douglas production function and can be used for the second order approximation.

The functional form of the stochastic frontier in this study is determined by testing the adequacy of the Cobb-Douglas relative to the less restrictive Translog. Since the two equations are nested, a likelihood ratio (LR) was used to test the null hypothesis that the Cobb-Douglas production function is an adequate representation of the data. The null hypothesis that a Cobb-Douglas production function specification is an adequate representation of the data was rejected in favor of the Translog production function (*LR = 196.77, p-value= 0.000*).

The two function forms are (translog production function and Cobb-Douglas) are written as follows:

[1]The Stochastic Frontier Analysis (SFA) is a production frontier technique of Aigner, Lovell, and Schmidt 1977 and is conceptually close to production function estimation. An econometric method that starts with the production function and then iteratively shifts it outward by a certain algorithm until a production frontier is obtained. In SFA, a farmers' observed output is modeled to deviate from the production-efficient frontier due to random noise and possibly production inefficiency.

$$lnY_i = \propto_i + \sum_k \beta_k X_{ik} + \frac{1}{2}\sum_k \sum_j \gamma_{ik} lnX_{ik} lnX_{ij} + \theta lnZ_i + \varphi lnS_i + v_i - \mu_i^* \quad \text{(Translog)} \quad (8)$$
$$lnY_i = \propto_i + \sum_k \beta_k X_{ik} + \theta lnZ_i + \varphi lnS_i + v_i - \mu_i^* \quad \text{(Cobb-Douglas)} \quad (9)$$

Where vector X contains economic inputs (seed, fertilizer and labor)), Z is a vector of control variables to capture heterogeneity in land quality, technology used and plot characteristics, S includes education and age of the household head. The full list of explanatory variables is presented in Appendix 2. In addition, we analyzed the determinants of inefficiency the parameters in Eqns. (5) and (7) were estimated using a one-step maximum likelihood estimation (MLE) which is generally proposed for simultaneous estimation of the stochastic frontier and the inefficiency effects. This is an important step as the results provide useful information for farmers to know the sources of their inefficiency and for policy makers to devise effective strategies and policies in order to enhance agricultural productivity in Zambia.

## 3. DATA

The data used in this study primarily comes from two waves of Rural Agricultural Livelihoods Surveys (RALS). These are nationally representative surveys conducted by the Indaba Agricultural Policy Institute (IAPRI) in collaboration with the Zambia Central Statistical Office (CSO) and the Ministry of Agriculture and Livestock (now Ministry of Agriculture) and cover the 2010/11 and 2013/14 agricultural season.

The RALS data sets provide comprehensive information on smallholder farm households cultivating less than 20 hectares of land for farming and /or livestock production purposes. The surveys are based on the sampling frame from the 2010 Zambian census and produce results that are statistically valid at provincial and national levels. For more details about the sampling frame used for RALS, see IAPRI (2012).

In the first wave of the survey (2010/11) 8,839 smallholder farm households were interviewed, while in the second wave covering 2013/14 agricultural season a total of 7,254 households were re-interviewed. For the econometrics analysis of this study, we used a balanced panel of 4,166 households that grew maize in both 2010/11 and 2013/14 farming seasons. We supplemented the RALS survey data with focus group discussions (FGDs) which were held in three provinces covering two districts in each province (Lundazi, Katete, Choma, Kalomo, Chibombo, and Mkushi districts). In each of the above-mentioned districts, two focus group discussions composed of both men and women smallholder farmers were conducted. Twelve FGDs were held and the group sizes ranged for 6 to 15 members. About 120 participants were involved in the focus group discussion in all the six districts of which 72 were male and 48 were female. The districts where purposively sampled and the focus was areas which have a relatively high percentage of farmers using improved technologies and animal traction. Appendix 4 gives a summary of the results from the FDG.

Table 1. below shows the distribution of the sample used for our analysis by province.

**Table 1. Sample Distribution by Province for Maize Fields**

| Province | Female HH % | | % plots controlled by female farmers in MHH | | % plots controlled by female farmers in FHH | |
|---|---|---|---|---|---|---|
| | 2012 | 2015 | 2012 | 2015 | 2012 | 2015 |
| Central | 17.62 | 15.26 | 2.07 | 1.10 | 97.96 | 96.67 |
| Copperbelt | 19.41 | 19.63 | 3.37 | 5.63 | 100 | 96.97 |
| Eastern | 19.70 | 21.77 | 3.90 | 3.14 | 95.23 | 97.71 |
| Luapula | 14.76 | 21.77 | 6.75 | 6.36 | 93.68 | 100 |
| Lusaka | 21.32 | 21.51 | 5.69 | 8.48 | 100 | 97.92 |
| Muchinga | 17.35 | 19.24 | 1.71 | 3.91 | 98.64 | 95.18 |
| Northern | 16.90 | 14.22 | 2.72 | 3.79 | 99.06 | 95.51 |
| North Western | 20.58 | 19.35 | 4.51 | 5.19 | 99.62 | 97.73 |
| Southern | 19.62 | 22.64 | 1.08 | 1.91 | 98.75 | 96.72 |
| Western | 26.97 | 30.12 | 6.05 | 7.14 | 98.04 | 98.17 |

Source: Authors Calculations from CSO/MAL/IAPRI (RALS) 2012 and 2015.

## 4. RESULTS

We begin this section by presenting some descriptive statistics regarding gender differences in access to agricultural resources, crops grown and input use. Sections 4.2 to 4.2.2. present and discusses the econometrics results.

### 4.1. Descriptive Statistics

#### *4.1.1. Gender Differences in Access to Agricultural Resources*

Table 2 below shows the gender differences in access to resources between plots controlled by males compared to those controlled by females. We further breakdown the plots controlled by females into two additional categories depending on the household headship, thus women farmers in male- and female-headed households respectively.

Consistent with what has been observed in most countries in Sub-Saharan Africa regarding women farmers limited access to productive agricultural resources, the results in Table 2 show that there is a significant difference between male and female farmers in terms of their access to agriculture extension, credit, labor, and land. Men are more likely to access these services and resources compared to their female counterparts. For example, more male famers had access to extension (75%) compared to 68% among female farmers in 2012. This disparity is similar for membership in cooperatives, and access to credit and key agricultural production assets such as land.

As you see below, these results are not very surprising, as other studies have found similar results in the past. Therefore, we went a step further to check to see whether household headship made a difference by comparing female farmers in male- and female-headed households.

**Table 2. Differences in Access to Agricultural Services and Resources**

| Variables | Average farmer | Male farmers | Female Farmers | ----Female farmers in - | |
|---|---|---|---|---|---|
| | | | | Male-HH | Female-HH |
| | A | B | C | D | E |
| Landholding size (ha) | 4.10 | 4.45 | 2.93 | 4.13 | 2.71 |
| Adult equivalent | 4.90 | 5.16 | 4.03 | 5.02 | 3.85 |
| Hectares cultivated (ha) | 1.26 | 1.37 | 0.87 | 0.91 | 1.07 |
| Commercialization Index | 0.37 | 0.40 | 0.28 | 0.30 | 0.28* |
| Member of cooperative (%) | 51.9 | 54.40 | 43.9 | 46.01 | 44.00* |
| Value of productive assets | 13,306 | 15,000 | 7,699 | 3,569 | 6,645 |
| Access to extension (%) | 73.70 | 74.70 | 68.01 | 74.00 | 69.30 |
| Access to credit (%) | 18.50 | 19.90 | 13.80 | 16.80 | 13.30* |

Source: Authors Calculations from CSO/MAL/IAPRI (RALS) 2012 and 2015.
Notes: Authors used pooled data from RALS 2012 and 2015 for results presented in Table 2.
T-test was done to compare differences between groups. Have indicated cases that are not statistically significant at 10%.
* shows no significance difference at 10%.

Interestingly, females in male-headed households tend to fare better than those in female-headed households. A comparison of the differences in access to productive resources (columns D and E) shows that on average, women in male-headed households are more likely to have access to agriculture extension, credit, productive assets, and land compared to women in female-headed households. However, in terms of area cultivated, women in female-headed households cultivate more land than those in male-headed households.

These results are consistent with the evidence that the constraints faced by female-headed households are more severe than when a household is headed by a male (Doss and Morris 2000; Koru and Holden 2008). These differences in access to productive resources could be one of the reasons why studies have found that women farmers lag behind in crop production and productivity. However, the presence of a male head to some extent helps to close the gap. This goes to reinforce the conclusion that women farmers alone tend to face greater hurdles in agriculture than males and females in male-headed households. This does not mean to say that females in male-headed households do not face their own hurdles in navigating intra household dynamics.

#### *4.1.2. Gender Differences in Crop Production and Input Use*

Table 3 presents the primary crops grown by smallholder farmers in Zambia. As a food staple, maize is the most grown crop among both male and female farmers; it has the highest percentage of fields for those under the control of men and those controlled by women. However, we find some big differences if we compare the results between female farmers by gender of household head. Similarly, for women in female-headed households, maize was grown on over 35% of the fields. However, in the case of women in male-headed households, less than 15% of the fields controlled by females were under maize. Instead, groundnuts were grown by over 40% of the female members in male-headed households compared to about 26% in households headed by another woman. Overall, more women tend to grow groundnuts than men regardless of the gender of the household head. Whilst a higher percentage of male farmers (7.5%) grew seed cotton as a cash crop compared to 3.65% among women farmers (columns B and C). This is consistent with evidence that men tend to control commercial crops and leave food crops to women. Crop commercialization has been found to disadvantage women especially in male-headed households. As highlighted by Njuki et al. (2011) in the case of Malawi and Uganda, agriculture commodities that generated high average income were more likely to be controlled by men than women. This may be the case for women farmers in male-headed households (Table 3, column D) where commercialization of maize in Zambia might result in more men controlling maize fields, whilst women are left to manage low value and less commercialized crops such as groundnuts, sweet potatoes, and mixed beans.

In terms of input use, Table 4 summarizes the differences in input use between plots controlled by men and those controlled by women. The results show that in general there is a significant difference in the use of agricultural inputs on plots managed by men and women. For example, male farmers are more likely to use fertilizer, hybrid seed, herbicides, and animal traction on their fields compared to their female counterparts. The quantity of fertilizer used in maize production is 33 kilograms higher among male farmers than among female farmers. However, in terms of the average seed rate used on both male and female plots, there is no significant difference.

**Table 3. Primary Crops Grown by Men and Women**

| Crop Choice | Fields for All households | Fields for Male Farmers | Fields for Female Farmers | --Female farmers in-- | |
|---|---|---|---|---|---|
| | | | | Male-headed HH | Female-headed HH |
| | A | B | C | D | E |
| Number of fields | 35,236 | 25,998 | 9,238 | 2,786 | 6,452 |
| % of field under | | | | | |
| Maize | 34.13 | 35.85 | 29.30 | 13.39 | 36.17 |
| Groundnuts | 23.25 | 20.63 | 30.65 | 42.39 | 25.57 |
| Cassava | 5.34 | 5.11 | 5.96 | 7.00 | 5.52 |
| Mixed beans | 7.22 | 7.16 | 7.39 | 9.33 | 6.56 |
| Sweet Potato | 7.32 | 6.92 | 8.44 | 13.24 | 6.37 |
| Seed Cotton | 6.52 | 7.55 | 3.65 | 1.72 | 4.48 |
| Sunflower | 5.27 | 5.75 | 3.90 | 3.48 | 4.08 |
| Millet | 3.64 | 3.60 | 3.77 | 3.84 | 3.74 |
| Rice | 2.44 | 2.42 | 2.49 | 1.58 | 2.88 |
| Soybeans | 3.24 | 3.48 | 2.59 | 2.51 | 2.62 |
| Sorghum | 1.62 | 1.54 | 1.86 | 1.51 | 2.01 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

Source: Pooled Data CSO/MAL/IAPRI (RALS) 2012 and 2015.

By gender of household head, results in Table 4 columns D and E show that female farmers living in households headed by males are more likely to use fertilizer and hybrid seed compared to female farmers in female-headed households—however, the difference is not significant for fertilizer use. Nevertheless, in terms of the rate of fertilizer applied, it is higher among female farmers in male-headed households compared to those in female-headed households. These results reinforce the earlier findings that show that female-headed households had less access to productive resources and key agricultural services such as credit, thereby, limiting their use of improved technologies.

**Table 4. Differences in the Use of Agricultural Inputs between Men and Women**

| Input use on Maize Fields | Fields for all HH | Fields for Male Farmers | Fields for Female Farmers | ---Female farmers in --- | |
|---|---|---|---|---|---|
| | | | | Male-HH | Female-HH |
| | A | B | C | D | E |
| Number of Cases | 8,061 | 6,190 | 1,871 | 285 | 1,586 |
| Fertilizer % | 60.95 | 64.22 | 50.13 | 53.00 | 49.06* |
| Hybrid seed % | 66.53 | 69.48 | 56.76 | 64.56 | 55,36 |
| Herbicides % | 5.21 | 5.67 | 3.69 | 5.61 | 3.34 |
| Animal Traction % | 40.18 | 41.87 | 34.58 | 30.52 | 34.31* |
| Ha planted Maize | 1.33 | 1.45 | 0.95 | 1.17 | 0.91 |
| Seed kg/ha | 26.01 | 26.97 | 25.74* | 26.80 | 27.01* |
| Fertilizer kg/ha | 211.04 | 218.33 | 185.39 | 195.92 | 180.52 |

Source: Pooled Data CSO/MAL/IAPRI (RALS) 2012 and 2015.
Notes: T-test was done to compare differences between groups. Have indicated cases that are not statistically significant at 10%.
* shows no significance difference at 10%.

## 4.2. Econometric Results

In this section, we discuss results from various econometric models. First, we briefly examine the factors affecting adoption of improved technologies including gender differences using CRE[2]. Second, we present results from models examining the gender difference in maize production and the effectiveness with which agricultural inputs are used to produce maize by both male and female farmers, herein after referred to as technical efficiency. We present results from two models for each of the improved technology estimated at plot level. In the first model, the unit of observation is the gender of the farmer (plot owner) regardless of whether the household is headed by a male or female-headed. Whilst in the second model, we separate the plot owners into two groups i.e., those in female-headed households and those in male-headed households by introducing two binary variables making this distinction in the model.

### *4.2.1. Factors Affecting Technology Adoption*

There are a number of variables from our analysis that show a positive and significant effect on technology adoption including education, household size, household commercialization index, extension services, and credit. However, we do not spend any time discussing these variables because our main objective in this study is to examine the impacts of gender. Results from Model 1 show that regardless of the gender of the household head, female farmers were less likely to adopt the use of hybrid seed, fertilizer, and animal traction compared to male farmers. On the other hand, the results show a positive coefficient on gender for adoption of herbicides; however, the results are not statistically significant. The positive sign may imply that women may be more willing to invest in labor saving technologies for weeding since they tend to disproportionate bear the brunt for weeding responsibilities. During the focus group discussions, farmers highlighted some of the benefits they have observed from using herbicides, one of which was the reduction in amount of time spent on weeding. However, despite these known benefits, the adoption of herbicides is still very low and the consensus from the farmers was that limited finances prevent them from adopting this technology. On the other hand, with the exception of models for herbicide use and fertilizer use for female farmers in male-headed household, Model 1 results show that female farmers irrespective of household headship are less likely to use hybrid seed, mechanization, and fertilizer.

These results support our descriptive statistics that adoption of improved technologies is lower among women, especially those in female-headed households compared to men and those in male-headed households. The constraints faced in female-headed households are more acute than those faced in male-headed households. Thus, within the male-headed households, female farmers may acquire fertilizer and other resources through their husbands more easily than females in female-headed households. In general, the results are consistent with findings from other countries that also reach the same conclusion that improved technology adoption among females is lower (Ragasa 2012; World Bank and IFPRI 2010).

To understand the reasons why female farmers were less likely to adopt improved technology, we turned to the results from the focus group discussions held in six districts in Zambia. From the discussions, farmers indicated that female farmers used hybrid seed but

[2] We also estimate the models using pooled probit. The results from pooled probit are in Appendix 3 for the interested readers but for the purposes of this paper our discussion focuses on results estimated using CRE.

also preferred local varieties for home consumption. They said, “It is believed that the volume of mealie-meal (maize flour) produces from the local seed is much larger than what is obtained from the hybrid seed”. They also indicated that the traditional varieties taste better and store better than hybrid seeds. In addition, local varieties were much cheaper to produce because no fertilizer was required compared to hybrid seed. The seemingly low cost of production for local maize varieties and the belief that is held by some farmers has prevented some farmers—especially women—from adopting improved maize varieties and fertilizer. Retention of traditional varieties is a common practice among female farmers whose production in most cases is limited to home consumption and opposed to their male counter parts. Lunduka, Fisher, and Snapp (2012) show similar findings in Malawi where smallholder farmers’ strong preference for particular traits found in local maize varieties such as ease of storage, high pound-ability, high flour-grain ratio, and favorable taste has assured the continued cultivation of local maize varieties. Therefore, empirical results that ignore these local dynamics tend to exaggerate the impact.

As mentioned in the introduction, other variables such as extension services, credit, and membership to farmer organizations have been cited in past studies to affect the adoption of technologies. To that effect, we interacted the gender variables with these variables to examine the differential impact of gender on technology adoption. In terms of access to agricultural credit, the results only show a positive and significant effect in adopting hybrid seed for women in male-headed households. The results show no significant effect in the adoption of animal traction, herbicides, and fertilizer. The findings also reveal that farmers who have access to credit are less likely to adopt herbicides. The results show that females in male-headed households who receive credit are 14% more likely to use hybrid seed compared to those not having any access to credit. These results suggest that removing liquidity constraints by making credit available among female farmers in female-headed households may help trigger more hybrid seed use in such households in Zambia. Nevertheless, the farmers interviewed in the FDGs complained that there were limited credit facilities available for smallholder farmers (especially female farmers) in Zambia, hence, their farming operations were not progressing due to liquidity problems. In cases were female farmers had access to credit, they could only be given very small loans that were usually too small to purchase animals or farm equipment that could help them improve their asset base as well as efficiency in farm production. In general, commercial banks and other formal financial institutions in Zambia were reluctant to give loans to smallholder farmers who are often characterized by low levels of assets ownership and lack of collateral to secure the loans. Hence, it is important for public and private entities to find creative financial solutions to harness the assets that smallholder farmers have (see Chapoto et al. 2015).

We use access to extension services and membership to a farmer cooperative to measure the extent to which farm households surveyed are exposed to information. The farmer organizations (cooperatives) are the main conduit that the Zambian government uses to distribute the subsidized hybrid seed and fertilizer to the smallholder farmers. It should, therefore, follow that farmers who are members of the cooperatives will have access to the subsidized inputs and are more likely to receive extension messages on the use of fertilizer and hybrid seed compared to non-cooperative members. Not all the other interactions were statistically significant. Results from our analysis show that membership to a farmer organizations (cooperatives) are positively correlated to adoption of improved seed, fertilizer, and mechanization. However, in relation to the gender of the field owner, membership to a farmer organization only shows a significant effect in adopting fertilizer and hybrid seed for women in male-headed households. While for women in female-headed households, the variable only shows a positive effect in adopting fertilizer.

With regard to access to extension services, in general this variable shows that farmers that had access to extension services were more likely to adopt hybrid seed, herbicides, and mechanization. The variable access to extension services on its own shows no significant effect in the adoption of fertilizer, but when interacted with the gender of the plot owner the effect is positive for female farmers residing in female-headed households. Furthermore, access to extension services shows a positive and significant effect in adopting herbicides among female famers in female-headed households. The general conclusion from the FDGs was that farmers would rather channel their finances to purchasing seed and fertilizer so that they are assured of *some harvest* as opposed to purchasing herbicides to control weeds in their fields and instead, use family labor or hired labor to weed their fields. Essentially, the farmers' expected benefit obtained from adopting improved seed and fertilizer is higher than what is obtained from adopting herbicides.

As highlighted in previous studies on technology adoption, availability of labor for a particular household can influence the ability to adopt certain technologies. In our study, we use household size as proxy for labor availability and this variable shows a positive effect in adopting hybrid seed, fertilizer, and use of herbicides. The results indicate that larger households are more likely to adopt these technologies compared to smaller households. It also reflects the important role that availability of family labor plays in the adoption of these technologies. According to Marenya and Barrett (2007), given that the bulk of labor from most farm operations is provided by the family rather than hired labor, lack of adequate family labor accompanied by inability to hire labor can seriously constrain the adoption of these practices. The variable however shows no significant effect in the adoption of herbicides. Adoption of herbicides reduces the demand for household labor to complete weeding activities. During the focus group discussions, a number of farmers indicated that with proper use of this technology, the task of applying herbicides in the fields can be completed within a few hours and may only require two to three individuals to complete the work. Therefore, the non-significance of the household size variable in the herbicides model is expected.

**Table 5. Factors Affecting Adoption of Improved Technologies Estimated Using CRE**

| Variables | Hybrid Seed=1 | | Fertilizer=1 | | Herbicides=1 | | Animal Traction=1 | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Female field owner | -0.112** | - | -0.086 | - | 0.009 | - | -0.038* | - |
| | (0.050) | - | (0.055) | - | (0.032) | - | (0.023) | - |
| Female in MHH | - | -0.095 | - | -0.065 | - | -0.400*** | - | -0.023 |
| | - | (0.081) | - | (0.080) | - | (0.039) | - | (0.044) |
| Female FHH | - | -0.139** | - | -0.027 | - | 0.017 | - | -0.039** |
| | - | (0.066) | - | (0.077) | - | (0.017) | - | (0.016) |
| **Interaction terms** | | | | | | | | |
| Female*Credit | 0.000 | - | -0.023 | - | -0.023 | - | -0.000 | - |
| | (0.038) | - | (0.038) | - | (0.020) | - | (0.016) | - |
| Female*Extension | 0.045 | - | 0.025 | - | -0.016 | - | 0.021 | - |
| | (0.030) | - | (0.031) | - | (0.017) | - | (0.016) | - |
| Female*farmer organization | -0.004 | - | 0.026 | - | 0.010 | - | -0.018 | - |
| | (0.029) | - | (0.030) | - | (0.014) | - | (0.013) | - |
| Female MHH*Credit | - | 0.138* | - | -0.068 | - | -0.020 | - | -0.002 |
| | - | (0.084) | - | (0.075) | - | (0.022) | - | (0.018) |
| Female MHH*Extension | - | 0.002** | - | 0.006* | - | -0.027 | - | 0.024 |
| | - | (0.076) | - | (0.071) | - | (0.017) | - | (0.017) |
| Female MHH*farmer org | - | 0.048 | - | -0.072 | - | 0.005 | - | -0.019 |
| | - | (0.070) | - | (0.066) | - | (0.015) | - | (0.015) |
| Female FHH*Credit | - | -0.025 | - | -0.015 | - | -0.042 | - | -0.019 |
| | - | (0.041) | - | (0.041) | - | (0.037) | - | (0.040) |
| Female FHH*Extension | - | 0.051 | - | 0.028 | - | 0.387*** | - | 0.009 |
| | - | (0.031) | - | (0.033) | - | (0.030) | - | (0.043) |
| Female FHH*farmer org | - | -0.009 | - | 0.041** | - | 0.039 | - | -0.010 |
| | - | (0.030) | - | (0.032) | - | (0.033) | - | (0.022) |
| **Other Explanatory Variables** | | | | | | | | |
| Age | 0.001 | 0.001 | 0.000 | -0.001 | 0.001 | -0.001 | 0.000 | 0.001 |
| | (0.003) | (0.003) | (0.004) | (0.004) | (0.002) | (0.001) | (0.001) | (0.001) |
| Age Squared | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Education | -0.002 | -0.003 | -0.000 | 0.000 | 0.001 | 0.004*** | -0.001 | -0.000 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.003) | (0.001) | (0.002) | (0.001) |
| Household size | 0.009** | 0.009*** | 0.009*** | 0.010*** | 0.003 | 0.003 | 0.001** | 0.001** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.001) | (0.001) | (0.001) | (0.001) |
| Landholding size | 0.000 | 0.000 | 0.000 | 0.000 | -0.000 | 0.000** | 0.001 | 0.001*** |
| | (0.002) | (0.002) | (0.001) | (0.001) | (0.000) | (0.000) | (0.001) | (0.000) |
| Household commercialization index | 0.231*** | 0.232*** | 0.083 | 0.082 | 0.041* | 0.047*** | -0.001 | 0.033*** |
| | (0.050) | (0.050) | (0.054) | (0.054) | (0.023) | (0.011) | (0.021) | (0.010) |

| Variables | Hybrid Seed=1 | | Fertilizer=1 | | Herbicides=1 | | Animal Traction=1 | |
|---|---|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| a.Conventional hand hoe (=1) | -0.131*** | -0.131*** | -0.068*** | -0.067*** | -0.026*** | -0.027*** | -0.347*** | -0.348*** |
| | (0.016) | (0.016) | (0.017) | (0.017) | (0.009) | (0.009) | (0.007) | (0.007) |
| Conservation Agriculture methods (=1) | -0.096*** | -0.095*** | -0.144*** | -0.144*** | 0.022** | 0.022** | -0.212*** | -0.213*** |
| | (0.027) | (0.024) | (0.029) | (0.029) | (0.010) | (0.010) | (0.009) | (0.009) |
| Ridging (=1) | -0.091*** | 0.095*** | 0.007 | 0.007 | -0.050*** | -0.050*** | -0.220*** | -0.221*** |
| | (0.018) | (0.018) | (0.019) | (0.019) | (0.009) | (0.009) | (0.008) | (0.008) |
| Soil Erosion | -0.033** | -0.033** | -0.028* | -0.028* | 0.004 | 0.004 | -0.003 | -0.003 |
| | (0.014) | (0.014) | (0.015) | (0.015) | (0.007) | (0.007) | (0.006) | (0.006) |
| Manure/Compost | -0.082*** | -0.082*** | 0.092*** | 0.091*** | -0.027*** | -0.028*** | -0.004 | -0.002 |
| | (0.013) | (0.013) | (0.014) | (0.014) | (0.006) | (0.006) | (0.005) | (0.005) |
| Member of farmer organization | 0.119*** | 0.118*** | 0.172*** | 0.170*** | 0.002 | 0.001 | 0.015 | 0.012** |
| | (0.028) | (0.028) | (0.028) | (0.028) | (0.014) | (0.007) | (0.012) | (0.006) |
| Access to Extension | 0.052* | 0.053** | 0.042 | 0.042 | 0.015 | 0.015* | -0.014 | 0.010 |
| | (0.027) | (0.026) | (0.026) | (0.026) | (0.014) | (0.008) | (0.011) | (0.007) |
| Access to credit | -0.056 | -0.055 | -0.097** | -0.097** | -0.009 | 0.005 | 0.002 | 0.005 |
| | (0.037) | (0.037) | (0.038) | (0.038) | (0.016) | (0.008) | (0.014) | (0.007) |
| Distance District Town Center | -0.001*** | -0.001*** | -0.001*** | -0.001*** | -0.000*** | -0.000*** | -0.000** | -0.000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Distance to Feeder Road | -0.004*** | -0.004*** | 0.000 | 0.000 | -0.000 | -0.000 | -0.000 | -0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| b. Agro Ecological Zone 2a | 0.004 | 0.007 | 0.096*** | 0.095*** | 0.057*** | 0.058*** | 0.018** | 0.020*** |
| | (0.028) | (0.028) | (0.026) | (0.026) | (0.017) | (0.018) | (0.008) | (0.008) |
| Agro Ecological Zone 2b | -0.226*** | -0.229*** | -0.225*** | -0.226*** | 0.018 | 0.018 | 0.019* | 0.014 |
| | (0.035) | (0.035) | (0.038) | (0.038) | (0.026) | (0.026) | (0.010) | (0.011) |
| Agro Ecological Zone 3 | 0.065** | 0.078** | 0.153*** | 0.152*** | 0.075*** | 0.075*** | -0.102*** | -0.101*** |
| | (0.029) | (0.029) | (0.027) | (0.027) | (0.018) | (0.019) | (0.010) | (0.010) |
| **Pseudo R2** | **0.2613** | **0.2621** | **0.2656** | **0.2668** | **0.1353** | **0.1388** | **0.8017** | **0.8018** |
| **Observations** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** |

Notes: a. Used ploughing as base;  b. Agro-ecological zone 1 as base.

### *4.2.2. Gender Difference in Maize Yield and Technical Efficiency*

The descriptive results presented in this paper shows that there is a significant difference in terms of access to agriculture resources between female- and male-field owners (see Table 2). However, these results though useful cannot tell us the *ceteris paribus* effects of the factors that contribute to yield difference on male- and female-controlled fields. Therefore, we estimated maize yield response and technical efficiency using stochastic frontier model as discussed in Section 2. Table 6 below shows the results for the maize yield response and technical efficiency estimates. The table shows results from both the translog and Cobb Douglas production functions but for the purposes of our study, we concentrate the discussion of the results on the translog production function. The results presented in Table 6 show the sources of differences in maize yield and technical efficiency among smallholder farmers in Zambia. We further demonstrate that the gender variable in our model shows no significant effect on the farmer's efficiency in maize production and yield.

In general, the model results show that access to agricultural information, credit, and membership to a farmer organization have a significant positive effect on the farmers' technical efficiency in maize production as well as on yields. Farmers who reported having contact with agricultural extension workers and belonged to farmer organizations had higher yields and were more efficient than those who did not. Furthermore, accessing credit for agricultural purposes can largely help farmers to invest and use improved technologies in their crop production. One of the constraints faced by smallholder farmers, especially women, in Zambia is lack of finances and this limits their use of hybrid seed, fertilizer, herbicides, and other technologies to improve their agricultural production.

The difference in the use of hybrid seed and fertilizer in maize production can also explain the variations in technical efficiency and maize yield among smallholder maize producers. On plots where farmers used fertilizer and hybrid seed, the technical efficiency scores and maize yields were higher compared to where farmers used local maize seed and where no fertilizer was used. These findings are similar to those of Chirwa (2007) in Malawi where the use of hybrid seed and membership to farmer groups increased the level of technical efficiency among smallholders maize producers.

Concerning the gender of a plot owner, we do not find any significant effect on the level of efficiency in maize production or yield. The results from the model go to show that gender of the farmer does not affect the farmers' productivity, but access to agricultural resources have a significant effect on their level of productivity.

**Table 6. Maize Yield Response and Technical Efficiency Results**

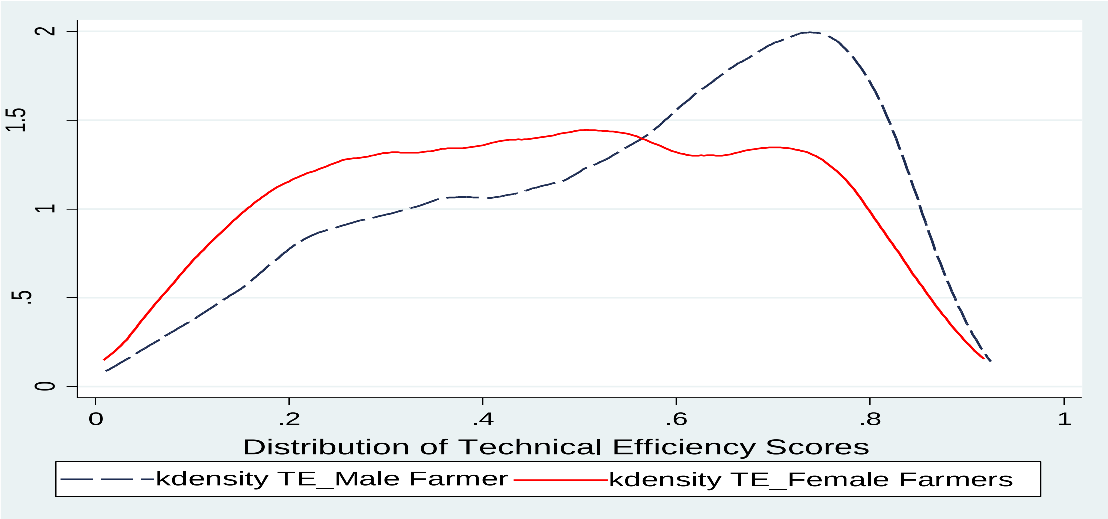
| Variables | Translog | Standard errors | Cobb Douglas | Standard errors |
|---|---|---|---|---|
| Log fertilizer | -0.182*** | (0.025) | 0.051*** | (0.004) |
| Log seed | 0.240** | (0.103) | 0.181*** | (0.017) |
| Log labor | -0.095* | (0.048) | -0.002 | (0.015) |
| Soil erosion (=1, 0 otherwise) | -0.042 | (0.030) | -0.074*** | (0.016) |
| ½ (Log fertilizer squared.) | 0.113*** | (0.006) | | |
| ½ (Log seed squared) | -0.005 | (0.032) | | |
| ½ (Log labor squared) | 0.055 | (0.035) | | |
| ***Interaction terms*** | | | | |
| Log fertilizer *Log seed | -0.037*** | (0.006) | | |
| Log fertilizer* Log labor | 0.006 | (0.006) | | |
| Log seed* Log labor | 0.025 | (0.034) | | |
| Log fertilizer* Soil erosion | -0.003 | (0.006) | | |
| ***Inefficiency Variables*** | | | | |
| Female head (=1, 0 otherwise) | -0.063 | (0.102) | -0.048 | (0.104) |
| Education level of head (yrs.) | -0.007 | (0.006) | -0.012** | (0.006) |
| Age head (yrs.) | 0.001 | (0.001) | 0.001 | (0.001) |
| Hybrid seed (=1, 0 otherwise) | -0.449*** | (0.056) | -0.530*** | (0.060) |
| Used fertilizer (=1, 0 otherwise) | -0.706*** | (0.068) | -0.448*** | (0.062) |
| Household Commercialization Index | -1.339*** | (0.113) | -1.298*** | (0.114) |
| Animal draft (=1, 0 otherwise) | 0.214*** | (0.043) | 0.296*** | (0.045) |
| Female field owner(=1, 0 otherwise) | 0.154 | (0.097) | 0.113 | (0.099) |
| Access to credit (=1, 0 otherwise) | 0.092* | (0.056) | 0.108* | (0.056) |
| Access to agricultural Information (=1, 0 otherwise) | -0.109** | (0.044) | -0.105** | (0.045) |
| Member Coop (=1, 0 otherwise) | -0.295*** | (0.054) | -0.322*** | (0.055) |
| Distance to the district town center (km) | -0.002*** | (0.001) | -0.002** | (0.001) |
| **Observations** | **8,134** | | **8,134** | |

Source: Authors Calculations from CSO/MAL/IAPRI (RALS) 2012 and 2015.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1 below shows the distribution of technical efficiency for male- and female-controlled fields. The estimated mean TE on male- and female-controlled fields is 55% and 48% respectively. Based on the results presented in Table 6, the factors that have a positive effect on technical efficiency in maize production include: access to agriculture extension services, access to credit, membership to farmer organizations, household commercialization level, and use of fertilizer and hybrid seeds. Since there is a significant difference between men and women in accessing the above mentioned resources as presented in the descriptive test statistics (Tables 2 and 3), it is, therefore, likely that the 7% gap in technical efficiency between men and women farmers is associated with the differences in access to agriculture resources.

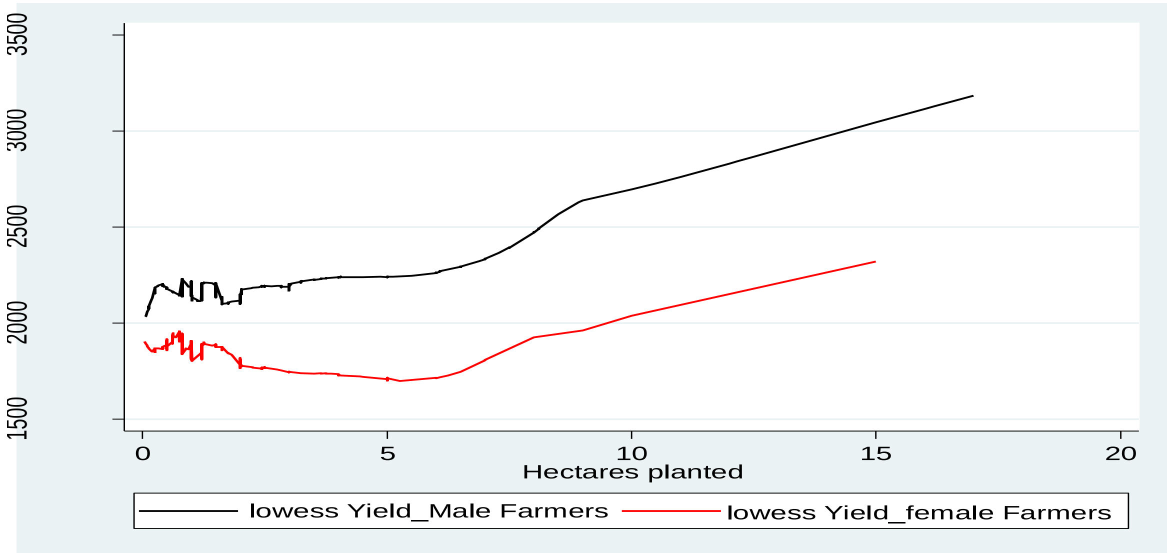
Although our results and findings from other studies (Quisumbing 1996; Koru and Holden 2008; Doss and Morris 2000) have shown that the gender variable does not affect the farmers productivity, the yield gap between male- and female-managed plots still exist among smallholder farmers. The average maize yield on plots controlled by men is 3.78MT while on plots controlled by females its 2.75MT. We illustrate this gap in yield using Figure 2 below.

**Figure 1. Distribution of Technical Efficiency for Female and Male Farmers**




Source: Authors Calculations from CSO/MAL/IAPRI (RALS) 2012 and 2015.

**Figure 2. Maize Yield Gap between Male- and Female-Managed Plots**




Source: Authors Calculations from CSO/MAL/IAPRI (RALS) 2012 and 2015.

Based on the descriptive statistics in Tables 2 and 3, there is a significant difference in terms of access to agricultural extension services, credit, use of improved seed and fertilizer between men and women farmers in Zambia. These differences contribute to the gap in yield that exists between the two groups of smallholder farmers. Closing this gap can largely improve the overall agriculture production among the smallholder farmers in Zambia and contribute to minimizing rural household poverty, which is prevalent in the female-headed households.

## 5. CONCLUSION

Using nationally representative household survey data supplemented by focus group discussions, this study addressed questions regarding gender differences in technology adoption. Firstly, we accessed whether there are gender differences in access to and use of productive resources between male and female farmers. The results from the bivariate analysis show that there are significant differences in access and use of productive resources between the two groups of farmers. Men generally were more likely to access credit, extension services, own and cultivate more land, and have high value of their productive assets compared to women. Similarly, women in male-headed households were more likely to access the productive resources compared to women in female-headed households. Our results are consistent with past research findings that show that on average the constraints faced by female-headed households are more severe compared to male-headed households.

Secondly, we looked at the factors that affect adoption of improved technologies among smallholder farmers with a specific focus on women. The analysis was conducted at plot and gender levels to examine the effect of gender in technology adoption as opposed to the traditional way of using the gender of the household head.

The econometric results show that for plots owned/controlled by female famers, the variable gender of the field owner had a negative effect on adoption of hybrid seed, fertilizer, and use of animal draft power. Thus, men were more likely to adopt hybrid seed, fertilizer, and use of animal draft power compared to women. The findings also show that education of the household head, household size, and access to credit and extension services significantly increased the likelihood of farmers adopting the use of fertilizer, hybrid seed, and animal draft power. However, concerning the use of herbicides, only education of the household head and access to extension services showed a positive effect on adopting this technology. The positive effect of the two variables on adoption of herbicides is consistent with the general conclusion from the focus group discussions where farmers indicated that lack of knowledge on the use of this technology is a major constraint that hinders farmers from adopting it. Therefore, it is expected that farmers who are more knowledgeable on their usage are more likely to use herbicides than those who are not. Furthermore, the results show that even farmers who had access to credit were less likely to adopt the use of herbicides. The general conclusion is that, in order to increase the adoption rates for herbicides, farmers need to be trained on the use of this technology either through extension visits or through farm field days.

We further interacted the factors that showed positive effects on the adoption of the technologies with gender of the field owner. The findings show that female farmers in male-headed households who had access to credit were more likely to adopt hybrid seed and use of animal draft power. Our results also show that female farmers in female-headed households who had access to agriculture extension and belonged to a farmer organization were more likely to adopt the use of fertilizer.

Thirdly, we examined the effect of technology adoption on farmers' productivity and technical efficiency in maize production. We also evaluated the factors contributing to technical inefficiency among the smallholder farmers. The variable of interest, gender of the field owner (female=1), showed no significant effect on farmer's technical efficiency and maize production. The variables that influence the technical efficiency of the farmers included age of the farmer, use of hybrid seed and fertilizer, and access to credit and extension services. The results show that use of fertilizer and improved seed increases maize yield among the smallholder farmers. In addition, they indicate that access to extension services, credit, and membership to a farmer organization enhances farmers' technical efficiency in maize production. The gender of the farmer however has no significant effect on the farmers' productivity and technical efficiency.

Lastly, having looked at the factors that are contributing to technical efficiency and maize yield we can conclude that the lower yields on female-controlled plots is due to their limited use of hybrid seed and fertilizer, less access to other productive resources, and not that they are inefficient in their production. Therefore, closing the gap in access to productive resources can help increase maize yield on female-controlled plots.

It should also be noted that men within the households have control over most maize fields in Zambia; this is largely because it is a source of income for many rural households. For most women that are growing maize, it is mainly for home consumption and they prefer using local seed varieties due to financial constraints. Encouraging women to participate in maize marketing can help increase the adoption of improved seed and use of fertilizers among this group of farmers. Furthermore, increasing the number of financial lending institutions that can provide small credit packages that are affordable to bring technologies to the poor farmers is another way that can help improve the rate of adoption among smallholder farmers. Government should also consider increasing the number of extension service workers that can help farmers (both men and women) gain the knowledge about the existing technologies.

**APPENDIX**

## Appendix 1. Variable Description and Statistics

| Variables | Mean | Min | Max | Standard Deviation | Expected Sign |
|---|---|---|---|---|---|
| Hybrid Seed (=1) | 0.63 | 0 | 1 | 0.48 | |
| Fertilizer use (=1) | 0.62 | 0 | 1 | 0.49 | |
| Animal Draft (=1) | 0.40 | 0 | 1 | 0.50 | |
| Herbicides (=1) | 0.037 | 0 | 1 | 0.189 | |
| Female Field Owner (=1) | 0.22 | 0 | 1 | 0.42 | - |
| Women in Female Headed Household (=1) | 0.173 | 0 | 1 | 0.378 | - |
| Women in Male Headed Households (=1) | 0.030 | 0 | 1 | 0.169 | + |
| Age of HH (yrs.) | 45.80 | 17 | 111 | 14.76 | -/+ |
| Education of Head (yrs.) | 6.43 | 0 | 19 | 3.99 | + |
| Adult Equivalent (count) | 4.97 | 0.63 | 24 | 2.32 | + |
| Landholding size (ha) | 4.29 | 0 | 502 | 8.75 | + |
| Household Commercialization Index | 0.39 | 0 | 1 | 0.30 | + |
| Member of Cooperative (=1) | 0.55 | 0 | 1 | 0.50 | + |
| Access to extension(=1) | 0.76 | 0 | 1 | 0.42 | + |
| Access to credit (=1) | 0.19 | 0 | 1 | 0.39 | + |
| Field prone to Soil erosion (=1) | 0.27 | 0 | 1 | 0.43 | - |
| Used Manure/Compost on the field (=1) | 0.09 | 0 | 1 | 0.29 | - |
| Dist. District Town Center | 39.29 | 0 | 250 | 31.83 | - |
| Agro-ecological Zone2a (=1)* | 0.47 | 0 | 1 | 0.287 | -/+ |
| Agro-ecological Zone2b (=1) | 0.05 | 0 | 1 | 0.499 | -/+ |
| Agro-ecological Zone3 (=1) | 0.41 | 0 | 1 | 0.481 | -/+ |

Source: CSO/MAL/IAPRI (RALS) 2012 and 2015.

*Agro-ecological zone 1 used as intercept.

## Appendix 2. Variables in Maize Response Model

| Variables | Mean | Min | Max | Standard Deviation |
|---|---|---|---|---|
| Fertilizer (Kg/ha) | 191.00 | 0 | 1,600 | 222.04 |
| Seed (Kg/ha) | 26.01 | 1.33 | 185.60 | 42.93 |
| Adult Equivalent (number) | 4.97 | 0.63 | 23.42 | 2.32 |
| Soil Erosion (=1) | 0.27 | 0 | 1 | 0.43 |
| ***Inefficiency Variables*** | | | | |
| Female Head (=1) | 0.19 | 0 | 1 | 0.39 |
| Education of HH head (yrs.) | 6.43 | 0 | 19 | 3.99 |
| Age head (yrs.) | 45.80 | 17 | 111 | 14.76 |
| Hybrid Seed (=1) | 0.63 | 0 | 1 | 0.48 |
| Used Fertilizer (=1) | 0.62 | 0 | 1 | 0.49 |
| Household Commercialization index | 0.39 | 0 | 1 | 0.30 |
| Animal draft (=1) | 0.40 | 0 | 1 | 0.50 |
| Female field owner(=1) | 0.22 | 0 | 1 | 0.42 |
| Access_ credit (=1) | 0.19 | 0 | 1 | 0.39 |
| Access agric. Information (=1) | 0.76 | 0 | 1 | 0.42 |
| Member Coop (=1) | 0.55 | 0 | 1 | 0.50 |

Source: CSO/MAL/IAPRI (RALS) 2012 and 2015.

**Appendix 3. Factors Affecting Adoption of Improved Technologies Estimated Using Pooled Probit**

| Variables | Hybrid=1 | | Fertilizer = | | Herbicides =1 | | Animal Traction =1 | |
|---|---|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| Female field owner | -0.066** | - | -0.057** | - | 0.007 | - | -0.037** | - |
| | (0.026) | - | (0.027) | - | (0.017) | - | (0.015) | - |
| Female in MHH | - | -0.085 | - | -0.062 | - | -0.400*** | - | -0.023 |
| | - | (0.064) | - | (0.063) | - | (0.040) | - | (0.044) |
| Female FHH | - | -0.064** | - | -0.055* | - | 0.017 | - | -0.039** |
| | - | (0.028) | - | (0.029) | - | (0.018) | - | (0.016) |
| **Interaction terms** | | | | | | | | |
| Female*Credit | 0.003 | - | -0.013 | - | -0.025 | - | -0.003 | - |
| | (0.038) | - | (0.038) | - | (0.020) | - | (0.017) | - |
| Female*Extension | 0.045 | - | 0.025 | - | -0.019 | - | 0.022 | - |
| | (0.030) | - | (0.031) | - | (0.017) | - | (0.017) | - |
| Female*farmer organization | -0.005 | - | 0.022 | - | 0.010 | - | -0.018 | - |
| | (0.029) | - | (0.030) | - | (0.014) | - | (0.014) | - |
| Female MHH*Credit | - | 0.140* | - | -0.073 | - | -0.020 | - | -0.002 |
| | - | (0.082) | - | (0.074) | - | (0.022) | - | (0.018) |
| Female MHH*Extension | - | 0.009 | - | 0.021 | - | -0.028 | - | 0.024 |
| | - | (0.075) | - | (0.073) | - | (0.017) | - | (0.017) |
| Female MHH*farmer org | - | 0.048** | - | -0.074 | - | 0.005 | - | -0.018 |
| | - | (0.069) | - | (0.066) | - | (0.015) | - | (0.015) |
| Female FHH*Credit | - | -0.021 | - | -0.001 | - | -0.042 | - | -0.019 |
| | - | (0.041) | - | (0.042) | - | (0.037) | - | (0.040) |
| Female FHH*Extension | - | 0.050 | - | 0.027 | - | 0.387*** | - | 0.009 |
| | - | (0.031) | - | (0.033) | - | (0.032) | - | (0.044) |
| Female FHH*farmer org | - | -0.009 | - | 0.035 | - | 0.038 | - | -0.010 |
| | - | (0.030) | - | (0.032) | - | (0.033) | - | (0.022) |
| **Other Explanatory Variables** | | | | | | | | |
| Age | 0.003 | 0.003 | 0.001 | 0.001 | -0.001 | -0.001 | 0.000 | 0.001 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.001) | (0.001) | (0.001) | (0.001) |
| Age Squared | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Education | 0.015*** | 0.015*** | 0.012*** | 0.012*** | 0.004*** | 0.004*** | -0.000 | -0.000 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) |
| Household size | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.003 | 0.003 | -0.001 | -0.001 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.001) | (0.001) | (0.001) | (0.001) |
| Landholding size | 0.003* | 0.003* | -0.001 | -0.001 | 0.000** | 0.000** | 0.001*** | 0.001*** |

| Variables | Hybrid=1 | | Fertilizer = | | Herbicides =1 | | Animal Traction =1 | |
|---|---|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| | (0.002) | (0.002) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Household commercialization index | 0.264*** | 0.264*** | 0.205*** | 0.205*** | 0.047*** | 0.047*** | 0.032*** | 0.033*** |
| | (0.024) | (0.024) | (0.024) | (0.024) | (0.011) | (0.011) | (0.010) | (0.010) |
| [a]Conventional hand hoe (=1) | -0.136*** | -0.135*** | -0.073*** | -0.072*** | -0.027*** | -0.027*** | -0.348*** | -0.348*** |
| | (0.017) | (0.017) | (0.017) | (0.017) | (0.009) | (0.009) | (0.007) | (0.007) |
| Conservation Agriculture methods (=1) | -0.103*** | -0.102*** | -0.156*** | -0.157*** | 0.022** | 0.023** | -0.213*** | -0.213*** |
| | (0.026) | (0.026) | (0.029) | (0.029) | (0.010) | (0.010) | (0.009) | (0.009) |
| Ridging (=1) | -0.097*** | -0.095*** | -0.002 | -0.002 | -0.050*** | -0.050*** | -0.220*** | -0.221*** |
| | (0.018) | (0.018) | (0.019) | (0.019) | (0.009) | (0.009) | (0.008) | (0.008) |
| Soil Erosion | -0.035** | -0.035** | -0.030** | -0.030** | 0.004 | 0.004 | -0.003 | -0.003 |
| | (0.014) | (0.014) | (0.015) | (0.015) | (0.007) | (0.007) | (0.006) | (0.006) |
| Manure/Compost | -0.074*** | -0.074*** | 0.095*** | 0.094*** | -0.028*** | -0.028*** | -0.002 | -0.002 |
| | (0.013) | (0.013) | (0.013) | (0.013) | (0.006) | (0.006) | (0.005) | (0.005) |
| Member of farmer organization | 0.239*** | 0.239*** | 0.280*** | 0.280*** | 0.001 | 0.001 | 0.012** | 0.012** |
| | (0.014) | (0.014) | (0.013) | (0.013) | (0.007) | (0.007) | (0.006) | (0.006) |
| Access to Extension | 0.060*** | 0.060*** | 0.014 | 0.014 | 0.015* | 0.015* | 0.010 | 0.010 |
| | (0.016) | (0.015) | (0.016) | (0.016) | (0.008) | (0.008) | (0.007) | (0.007) |
| Access to credit | 0.100*** | 0.100*** | -0.039** | -0.039* | 0.005 | 0.005 | 0.005 | 0.005 |
| | (0.019) | (0.019) | (0.020) | (0.020) | (0.008) | (0.008) | (0.007) | (0.007) |
| Distance District Town Center | -0.001*** | -0.001*** | -0.001*** | -0.001*** | -0.000*** | -0.000*** | -0.000** | -0.000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Distance to Feeder Road | -0.004*** | -0.004*** | 0.000 | 0.000 | -0.000 | -0.000 | -0.000 | -0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| [b]Agro Ecological Zone 2a | 0.007 | 0.008 | 0.101*** | 0.100*** | 0.057*** | 0.058*** | 0.020*** | 0.020*** |
| | (0.028) | (0.028) | (0.026) | (0.026) | (0.018) | (0.018) | (0.008) | (0.008) |
| Agro Ecological Zone 2b | -0.230*** | -0.230*** | -0.224*** | -0.226*** | 0.019 | 0.019 | 0.015 | 0.014 |
| | (0.035) | (0.035) | (0.038) | (0.038) | (0.026) | (0.026) | (0.011) | (0.011) |
| Agro Ecological Zone 3 | 0.078*** | 0.078*** | 0.175*** | 0.175*** | 0.074*** | 0.075*** | -0.101*** | -0.101*** |
| | (0.030) | (0.030) | (0.027) | (0.027) | (0.019) | (0.019) | (0.010) | (0.010) |
| **Pseudo R2** | **0.2556** | **0.2562** | **0.2586** | **0.2596** | **0.1293** | **0.1326** | **0.8105** | **0.8005** |
| **Observations** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** | **8,134** |

[a] Used ploughing as base.
[b] Agro-ecological zone 1 as base.

## APPENDIX 4. SUMMARY FROM FOCUS GROUP DISCUSSIONS

Focus group discussions were held in three provinces covering two districts in each province; Eastern Province (Lundazi, Katete); Southern Province (Choma, Kalomo); and Central Province (Chibombo and Mkushi districts) with a total of 120 farmers.

In general most of the farmers indicated having adopted the use improved (hybrid) maize seed and fertilizer compared to herbicides and animal draft power. They also indicated that the despite their use of hybrid maize seed, they still allocate a portion of land for local maize variety, which they find easy to grow since it doesn't require much use of fertilizer. Furthermore, adoption of herbicides was very low among the smallholder farmers and the general indication from the farmers was that most of them lacked the knowledge of how to use them. The misconception that herbicides destroy land and crops has also resulted in the low adoption of this technology. On the other hand, the use of animal draft power poses a challenge for most of the farmers who do not own animals. Respondents cited high cost of hiring animals for tillage, hence, they simply used the traditional hand-hoeing method.

The farmers indicated that lack of finances curtailed their adoption of the new technologies. The majority of the small-scale farmers interviewed indicated that they adopted hybrid seed and fertilizer because they received subsidized fertilizer and maize seed from inputs through the Farmer Input Support Program (FISP). However, some of the larger farmers complained that the inputs from FISP were not enough to be planted on all their areas and, in some cases, they had to share the FISP pack with other farmers. This meant they had to supplement their seed requirements by also growing local seed.

In terms of the rate of adoption of improved technologies between men and women, women farmers indicated that men were fast to adopt the new technologies—faster than women were—because they were heads of the household and they control the use of income within the households. When farmers were asked about the issue of land access, with exception of Mkushi district, farmers from the other districts indicated that land is only accessed through the head of the household who in most cases was male. Only in the event where a woman is divorced or widowed can they be allowed to own a separate portion of the land. One farmer in Eastern Province, indicated that, "As men we own land since we are the head of the household and traditionally it's a taboo for a married woman to go and request for land from the local leaders; she is expected to be a helper on the husband's plot. If we give our women a portion of land for them to cultivate for themselves they become *big-headed* hence we prefer to control the land ourselves." While farmers in Mkushi district indicated that women were free to own land regardless of their marital status all they needed was money to purchase the land and cultivate what they wanted. These discussions reinforce the disparities that exist in terms of land access by female farmers in Zambia. Although, the issue of access to land among women varied across the different ethnic groups, the majority of women in the rural parts of Zambia faced similar traditional barriers that prevented them from accessing land.

In addition, farmers cited lack of availability of financial lending institutions as one of the factors that contribute to limited access to credit. They indicated that there are very few financial lending institutions available in their districts and the most common one is Lima Credit from Zambia National Farmers Union (ZNFU), which they considered to favor a few larger farmers. The credit facility required farmers to cultivate at least five hectares of land, hence, prevented small-scale farmers—especially women—from accessing such schemes. Most women in the focus group discussions indicated that they were very skeptical to access loans for fear of losing their limited assets if they fail to pay.

In all the three provinces, farmers highlighted the following as ways that could help them in terms of adopting improved technologies:

- The need for an increase in the number of public and private institutions that offer input credit to smallholder farmers, but the conditions needed to be more favorable to allow them to borrow without the fear of failing to payback. The current situation where farmers are too dependent on FISP was not helpful because the pack would not be large enough to fulfill their needs.
- Need for an increase in the number of agro-dealers that supply farming inputs. Some districts had very few reliable sources of farm inputs, which meant farmers had to travel long distances to access these inputs. However, poorer farmers could not afford the additional cost of transportation.
- If the government is to continue with the traditional FISP, government should consider including a starter pack for herbicides in the FISP pack, as this would encourage more farmers to try out the technology on their farms. However, because of the challenges of late delivery of the packs, farmers indicated that the private sector needed to fill the void.
- The farmers lamented the late payments from the Food Reserve Agency (FRA) and said that this was contributing to their inability to purchase seed, fertilizer, and other inputs on time.
- The government needed to strengthen the extension system, especially by increasing the number of extension officers within the districts. The respondents indicated that they were now relying on other farmers to learn about the new technologies available and this was not enough.
- The disparities in crop production between men and women were due to the absence of a reliable market for those crops considered *female crops*. Other farmers advocated for FRA to also start buying groundnuts as a way of motivating farmers to grow the crop. Others advocated for more private sector involvement in the marketing of their crops.

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